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Statistical evaluation of the composition, physical properties, and surface configuration of a terrestrial test site and their correlation with remotely sensed data.

Interim Progress Report - March 31, 1965

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INTRODUCTION:

Although a lot of time since August 1, 1964, was involved with literature searches and general orientation, significant progress has been made towards the goals of this research project. Two questionnaires were circulated to investigators involved in the NASA remote sensing projects. Members of the Northwestern team made two separate visits to the Pisgah Crater Test Site, California, and undertook extensive sampling programs; a start has been made toward working up the data from the collected samples and from extensive photographic records.

CONCEPTS:

We have gained a reasonably clear concept of the initial statistical problems that will be involved in predicting the nature of a sensed area ('ground truth') with the aid of remote sensors. Undoubtedly, as our work proceeds additional problems will emerge, but it is already clear that the sampling and statistical problems are considerably more complex than had been anticipated. A major manuscript is being prepared with the intention of exposing some of the principal difficulties; it is hoped that such a paper will be useful to all experimenters in sharpening the focus on specific problems and objectives associated with remotely sensing ground truth.

Some of the problems may be briefly stated. Statistical quantitative models must be erected for the following:

(i) data concerning those geological attributes traditionally studied by geologists. These appear to fall in two categories:

(a) geometrical attributes of the surface (e.g., joints, terrain, relief, roughness, etc.), and

(b) physical and chemical properties of the earth's surficial rock units; sometimes as many as 140 attributes have been measured for individual hand samples, and 300-500 attributes could be measured.

(ii) data concerning the materials at the earth's atmosphere-lithosphere interface that could be subjected to remote sensing. At present there is essentially no quantitative information about the nature and distribution of wind blown dust, silt, and sand, disaggregated debris, desert varnish, caliche, soil, etc.

(iii) remotely sensed data.

Methodology for distinguishing the most significant variables from the many hundred that can now be measured directly or by remote sensing is urgently required in order to abstract the optimum information from the expensive numerical data. Several concepts (and computer programs with which to test them) that permit an initial exploration of significant methods have already been developed by members of the Northwestern team. Additional work is required to extend these techniques to data derived from remote sensing experiments.

A specific attempt is being made to develop statistical models that permit correlation of (iii) with (i) and/or (ii) for stated variables. This work raises several questions that require urgent attention, e.g.,

1. What are the objectives of the sensing? Answers to this question will involve precise operational definitions of 'ground truth' attributes.
2. How many attributes need to be measured (estimated) to satisfy the objective?

3. Is it practicable to measure the most important attributes, or must they be estimated from measurements of closely correlated variables that can be estimated more easily?

Experience in the more traditional fields of geological enquiry has shown that strong correlations exist between many variables (e.g., variables drawn from closed number tables). The variance of each attribute within samples of constant size is in general different. The variance of a specified attribute within samples of dissimilar size is commonly different. Each attribute measured for samples of constant size is a dependent variable with respect to geographic location, so that $X_{ns} = f(U,V)$, where X_{ns} is the nth attribute for samples of size s, and U and V are orthogonal geographic coordinates. Confidence limits can be associated with predictions of X_{ns}, but, unless the sampled and target populations are the same, statistical inferences about the target population cannot be based on data drawn from the sampled population (Whitten, 1961, 1964).

Materials at the atmosphere-lithosphere interface undoubtedly follow similar rules, but, unfortunately, there is essentially no information about their quantitative nature and geographical variability. In fact, so little attention appears to have been given to such materials that operational definitions must be erected before they can be adequately sampled and measured. Undoubtedly relationships such as $Y_{ms} = F(U,V)$ exist, where Y_{ms} is the mth attribute for samples of the atmosphere-lithosphere interface materials of size s.

At present it is not known whether, in general, it will be possible to make predictions about X_{ns} on the basis of Y_{ms} (e.g., whether functions of the type $X_{ns} = G\ (Y_{ms})$ would have any general usefulness for prediction purposes). In a few special cases evidence for such correlations exists (*e.g.*, trace element concentrations in certain plants have been correlated with mineralization under the soil zone). This is an important topic because many remote sensors will probably estimate Y_{ms}, although a geologist is commonly only interested in X_{ns}. As a specific example, some of the basalts at Pisgah that bear a desert varnish veneer may be considered; some sensors may chiefly respond to the desert varnish which has markedly dissimilar attributes to the basalt mapped by the geologist.

The required statistical models are likely to be complex. In addition to textural, chemical, physical, and other allied attributes, numerous external variables (*e.g.*, temperature and moisture) are likely to affect some, but not all, of the Y_{ms} attributes. For example, clay minerals, zeolites, etc., change their properties under different climatic conditions; again, the salts at the surface of a playa tend to vary seasonally. Thus, $Y_{ms} = F(U,V,R)$ should probably be considered, where R is a whole range of external phenomena (variables).

It can be concluded that the objective - the particular aspect of ground truth - sought after is highly significant in designing statistically-significant experiments. For different objectives, different attributes need measuring. To differentiate a sedimentary from an igneous silicate rock of analogous bulk composition, or a sand dune from a quartzite, or a jointed from an unjointed rock, different attributes must be measured. In most cases models based on the remotely sensed data will not yield the required ground truth directly; rather, correlations will need to be established between the sensed attributes, S_{Ns}, and X_{ns} and Y_{ms}. Such techniques are not uncommon in studies of directly-measured attributes. For example, Vistelius (1962) predicted the P_2O_5 content of samples of a granite from Tien Shan, Russia, by expressing this attribute as a polynomial function of modal variables, thus:

$$P_2O_5 = a_0 + a_1Q + a_2K + a_3P + a_4M$$

where Q, K, P, and M are modal volume percentages of quartz, potash feldspar, plagioclase, and mafic minerals, respectively. It seems likely that a specified attribute could be predicted on the basis of an array of different remotely-sensed attributes provided

$$S_{Ns} = g\ (U,V,R)$$

where S_{Ns} is the Nth remotely-sensed attribute for sensed sample areas of size s. To measure N attributes with identical U, V, and R independent variables may be difficult experimentally.

In remote sensing U and V will commonly represent areas 'seen', and one can legitimately enquire what precision is needed in locating U and V; expressed differently, what degree of homogeneity do the sensed attributes have with respect to U and V. As pointed out above, the variance of each attribute is, in general, dissimilar in this respect. Hence, a significant question must be posed: If sensors carried on the same platform sense neighboring locations of slightly dissimilar size, are the results significantly less useful than if identical sized and located sites are sensed in each integration? Intuitively, on the basis of experience gained with traditional rock attributes, it seems highly likely that dissimilar size and location would make the sensed data considerably less significant. Specific sample collecting has been undertaken at Pisgah Crater Test Site in an attempt to obtain some specific information on this problem. A wide range of attributes is being measured and preliminary results will be made available as obtained.

In general, it would seem that the severe statistical problems involved in establishing ground truth on the basis of any form of remote sensing force the conclusion that at least one very simple test site should be studied. Sampling at Pisgah has already demonstrated that the area is extraordinarily heterogeneous and statistically complex - especially with respect to attributes of type Y_{ms}. So little has ever been recorded about the nature of the atmosphere-lithosphere interface in well-exposed areas, that it is proposed to make an informal survey of this topic in a variety of different areas. Casual observation suggests that the amount of unadulterated bedrock exposed in desert terrains is extremely small - possibly less than in many non-desert areas.

After preliminary data have been developed and statistical models have been prepared for portions of several test sites, various discriminant functions should permit ground-truth models to be evaluated.

QUESTIONNAIRES:

An initial questionnaire (Table I) was distributed on September 18, 1964, to determine the variables sensed by apparatus being developed by NASA experimenters, the area sensed at one time, the target of interest, and the effect of grain size and terrain on the experiments. The twelve responses are summarized in Table II. Following the October 13, 1964, meeting at Ann Arbor, Michigan, a second questionnaire (Table III) was distributed on December 3, 1964. The six replies received to date are summarized in Table IV.

TABLE I

QUESTIONNAIRE I : ISSUED SEPTEMBER 18, 1964

We ask all groups collecting remotely sensed data to give us advice on the following points:

1. Variables to be sensed: What variables will the sensor you are working with measure? - e.g., What elements in bulk rock?
   What oxides in bulk rock?
   What minerals in bulk rock?
   What other variables?
   (e.g. radioactivity,etc.)
2. Area sampled at one moment: What is the power of resolution of the sensor you are working with? That is, what area of the ground surface (square or circle of ground?) will be evaluated by any one reading? Will you be involved with a single value for each measured variable for each unit area, and continuous reading recorded during a traverse, or photographs of areas?
3. Target of interest: Some sensors evaluate the immediate ground surface; others penetrate beneath the immediate surface. Will your sensor evaluate (a) the extreme outer surface, (b) the rocks within inch or so of surface (as in normal geological work), or (c) rocks at some specified depth under ground surface?
4. To what extent are factors like average or range of grain size and terrain type significant to evaluation of the sensor data with which you are dealing?

TABLE I (CONTINUED)

I am sorry to bother you with these questions, but it is unrealistic for us to commence work without firm answers to all of these questions. I would greatly appreciate your cooperation and prompt reply. A questionnaire is enclosed which you might care to use instead of writing a letter.

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RETURN TO: E. H. Timothy Whitten
Department of Geology
Northwestern University
Evanston, Illinois

FROM:
Name -

Address -

Geological variables to be included in 'ground truth' evaluations

1. Variables to be sensed:
   (a) elements in bulk rock:
   (b) oxides in bulk rock:
   (c) minerals in bulk rock:
   (d) additional variables of interest:

2. Area sampled at one moment:
   (a) Ground area evaluated at one reading:
   (b) Is the area a rectangle, square or circle?
   (c) Single reading each variable each unit area? Yes/No
   Continuous record during traverse? Yes/No
   Photographic-type record? Yes/No
   Other (explain)

3. Target of interest:
   (a) extreme outer surface of Earth Yes/No
   (b) rocks within inch or so of surface Yes/No
   (c) rocks at specified depth below ground Yes/No
   What depth?

4. Is average or range of grain size significant? (Please explain)

5. Is average or range of terrain significant? (Please explain)

TABLE II : REPLIES TO QUESTIONNAIRE I.

Contributor	Variables to be sensed	Area sampled at one moment	Target of interest	Significance of grain size	Significance of terrain
R.N. Colwell	Light reflectance of surface Spectral range : 380-1000Å Photographic tones	100 in^2 for spectrophotometer Circle Single & continuous record Several mi^2 for photos	Surface & inch or so below	Yes, Texture affects light re - flection & photographic tone	Yes, same as grain size.
J.O. Morgan	Thermal expression at surface	Dependent on altitude 1-100 $ft.^2$ square. Continuous & photo record Infrared radiometric measurement	Surface & inch or so below Deeper questionable	No sign	Probably no sign. Picture record of distribution of radiant energy from surface.
R.J.P.Lyon	Bulk chem. composition and possibly SiO_2, Fe-Mg ratios, etc. Qtz., feldspar, pyroxene; qualitatively & perhaps quantitatively. Roughness & particle size of dust, sand & soil overlying rock.	0.7 sq. degree (≃370x75ft.@2000ft) and 120 knots ground speed (2 secs integration). Rectangle (projection of slit) moved forward by motion of aircraft Record - single & cont. Infrared radiance within rectangle is integrated to yield one reading. Rectangle may be made a line if slit-length parallel to flight.	Surface & possibly slightly below "That's a good question!"	Yes, if surface sandy or powdered or xtl size small in rock the emittance is difficult to identify.	Yes, Roughness (macro & micro) can markedly affect the infrared emittance quality.
J.B. Adams	Spectrel reflectivity (3000-10,000 Å) Arrangement of elements & oxides (into minerals) probably governs spectral features.	100 $ft.^2$ to 100 $mi.^2$ Circle Photographic-type record	Surface	No, spectral imagery does not resolve points at this scale	No
J.R. Shay	Concerned with agricultural crops and soil conditions. Imagery from ultraviolet to far infrared.				

Contributor	Variables to be sensed	Area sampled at one moment	Target of interest	Significance of grain size	Significance of terrain
W.H. Peake	Dielectric constant, conductivity, and, perhaps, magnetic permeability of surface layers	About 1 ft.^{2}, an ellipse Integrated (average) of variable over 100 by 1 foot strip.	Surface an inch or so below	Yes, surface structure has large effect on radar return & radiometric temperature at microwave freq.	Yes, at certain angles of incidence the R.M.S. slope of the terrain may control radar return.
C.C. Mason	Elements in bulk rock. Spectral region - 2000-3000 Å (Response of surface due to bombardment by solar radiation below 3000 Å)	Approx. 100 ft. diameter circle Single spectogram reading/unit area	Surface	No	No
	Method may not be subject to "ground truth" evaluation since most energy filtered out by atmosphere.				
R.K. Moore	Dielectric & conducting properties Average roughness & shape of homogeneous objects, including structurally-influenced topography	NRL aircraft—approx. 200' x 160' rectangle at 2000 ft. (5° azi, beam width) Form of record not established (16 parameters-4freq.x4 polar.comb.) WADC aircraft - continuous strip 3500 ft. to either side of craft with 2000 ft. gap below. Photo record with 50' x 50' resolution per point Also, radar, infrared & visible sensor records Classified aircraft - high resolution images	Penetration depends on conductivity which depends on moisture. Inch or two on wet surfaces & several feet in dry Penetration of vegetation depends on density and moisture content.	Only grain sizes of tens of centimeters & larger will be highly significant Properties of radar signal determined by geometry of surface. Ohio State studying scattering properties of small patches (1 ft^2) of ground with surface vehicle.	Averages primary thing seen—range of variation of these averages will be thing trying to detect.

Contributor	Variables to be sensed	Area sampled at one moment	Target of interest	Significance of grain size	Significance of terrain
A.R. Barringer	Analysis of SO_2 and I_2 content of air between satellite and ground using spectrophotometric methods. VHF reflectivity in 75-150 mc region.	1° solid angle 60° solid angle modified by specular reflection	Air above surface Penetration depends on moisture content: can be several feet. "Chirp" signal can detect soil layering.	None None	Geology and weathering affect development of vapors. Rugged topography creates major difficulties.
W.A. Fischer	Elements, oxides, minerals (species and modes) Index of surface roughness Dust composition & variations in thickness (or per unit area)on rock surface.	Ground radiometers - max.: 30° (.5 ft. at 1 ft.) min.: 3° (.05 ft. at 1 ft.) Airborne infrared scanner - 4 ft./1000 ft. altitude, normal to surface. Densitometer - Dependent on aperture and scale of imagery. Area from 3 ft. to 2 miles at orbital altitudes. Circular area sampled. Single readings in ground survey, continuous with aerial scanner. Photographic-type record. (Data may be stored on tape.)	Surface and ~~inch~~ or so below.	Affects emissivity (through surface configuration) and transmissivity and ability to retain moisture.	Topography controls shadow and causes variation in temperature emissivity.
M.R. Holter	Relative apparent surface temperature. Emissivity Thermal conductivity Heat capacity Relative spectral reflectance (UV to long IR)	Function of altitude, FOV of camera. Thermal data using optical-mech. scanners in order of milliradians, thus, at 1000 ft. area sampled in the order of feet. Area approx. a square. Photographic-type record.	Extreme outer surface. Since surface temp. affected by heat conductivity and capacity of lower levels, evaluation of rocks below surface anticipated.	A greater variety of terrain types and range of rock sizes is preferred to obtain more general information. If only sizes tested are smaller than instantaneous field of view, then averaging and surface effects (roughness) can affect apparent temperature measurement and in some cases reduce the contrasting temperature between two different rock materials.	

Contributor	Variables to be sensed	Area sample at one moment	Target of interest	Significance of grain size	Significance of terrain
B.B. Scheps	Objective color sensors: The 'true' color of rocks, soils, vegetation, etc. (Independent of illuminant or observer-spectral color.)	Not presently known Probably a photographic-type record, maybe a strip chart.	Surface	As a measure of texture and hence specularity of the surface as a reflector.	Probably none
	Radar photography: Size, spacing, geometry (micro & macro) Dielectric constant, conductivity, soil moisture	Not easily defined. Use 50 ft. square cell. Continuous photographic-type record. May also have associated signals.	Surface down to not deeper than 4 ft. in dry soils.	Size, distribution, geometry vital in understanding back scatter characteristics of the terrain as a reflector	At several scales: micro (grain size), macro, local area and regional geomorphology.

TABLE III

QUESTIONNAIRE II : ISSUED 3 DECEMBER, 1964

Statistical problems associated with 'Ground Truth':

1. What is 'ground truth' in terms of your sensing experiment?
2. There are many hundreds of attributes of rocks and the areal variability of each attribute is dissimilar; thus, we need some guide as to which attributes will affect your experiment before considering specific statistical problems involved in establishing ground truth. Please indicate, being as specific as possible, what attributes you wish to have information about in terms of ground truth. Particularly emphasize the attributes of the rocks and ground surface that are significant to you*.
3. What is the size of resolution of your equipment if flown at the following altitudes:

   1000 feet. . . . .
   5000 feet. . . . .
   10000 feet. . . . .
   20000 feet. . . . .
   40000 feet. . . . .
   10 miles . . . .
   50 miles . . . .
   100 miles . . . .
   200 miles . . . .

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* Examples include: Weight % all major oxides in total rock; weight % or p.p.m. all trace elements in total rock; weight or volume % of each major and accessory mineral in total rock; weight % of major and minor elements in each major and accessory mineral component of rock; textural features of rock (e.g., grain-size, mean, skewness, kurtosis of grain-size, grain shape, megacrysts, etc.); porosity, electrical resistivity, inclusions, etc.; specific gravity; superficial covering of sand, silt, clay, dust - type and amount which is important; structural attributes of rock (e.g., preferred orientation of grains, jointing, shattering); surface characteristics of rock in terms of roughness, slope, etc., etc.)

TABLE III (CONTINUED)

4. At this time do you have any recommendations as to the altitude at which your experiment should be flown in aircraft for the acquisition of test site data?

   Does your equipment record instantaneously, or is the record smeared due to aircraft speed (Lowest aircraft ground speeds: Convair 240: 200 ft/sec; Convair 990: 630 ft/sec)?

   What is the integration time of your equipment? Does equipment sense in same portion of spectrum throughout whole integration time? If not, how will this affect attributes being sensed from moving platform?

5. Since several sensors have very high resolution (e.g., one square foot when carried in aircraft, or fraction of foot when used on ground), it would be prohibitive to provide precise ground truth on the basis of such small unit areas (even for a 10 square mile test site). So that all high-resolution sensors test the same precise areas, would you be prepared to agree on one, two or three semi-permanent traverses or subareas at Pisgah Crater in order that ground truth can be maximized?

   If yes, please designate (on the basis of your preliminary work at Pisgah) one to three optimum localities for you; these subareas will hopefully cover a sufficient variety of surface features and rock composition. They could probably be defined on Dr. Colwell's low altitude aerial photos or marked on the ground in a semi-permanent manner).

Name of respondent ______________________

Date ______________________

LIST OF INVESTIGATORS TO WHOM QUESTIONNAIRE II WAS SENT

Dr. Peter C. Badgley

Dr. William Tifft

Mr. James E. Gillis, Jr.

Dr. R. N. Colwell

Dr. John B. Adams

Dr. John F. Cronin

Mr. Bernard B. Scheps

Mr. M. W. Krueger

Dr. William A. Fischer

Dr. Stephen J. Garawecki

Dr. Ronald J. P. Lyon

Dr. James E. Conel

Dr. William Nordberg

Dr. Richard K. Moore

Dr. David S. Simonett

Dr. William H . Peake

Dr. Isadore Katz

Dr. H . Cameron

Dr. Frank Barath

Dr. Robert C. Speed

Dr. D. Jones

Dr. E. D. McAlister

Mr. J..Green

Dr. A. R. Barringer

Mr. Leo F. Childs

Mr. K. R. Webster

Mr. R. R. Stephens

Mr. Rollin W. Gillespie (for his interest only)

TABLE IV: - REPLIES TO QUESTIONNAIRE II

Contributor	Definition of ground truth & rock attributes to be studied	Resolution of sensors at various altitudes	Resolution & integration properties of sensor	Can sub-areas be selected to maximize ground truth?
Bernard Scheps GIMRADA	(Radar) Attributes: textural features, electrical resistivity, superficial surface cover, structural attributes, surface characteristics, moisture content. Also: soils, vegetation, cultural objects; "the state and status of all."	Use responses of R.K. Moore	Either instantaneous or smeared records possible Variable integration time Senses same spectral band.	Okay for Pisgah (moon analog) Also desires other areas; suggests Wilcox Dry Lake as being uniform, possible simplifying case.
James E. Conel JPL	(Infrared spectrophotometry) Ground truth consists of knowlege of following parameters: Temperature distribution & extent of "local thermodynamic equilibrium" (to a depth of a few centimeters) Scattering & absorption coefficients of near surface materials (to depth of mm) Degree of vertical homogeneity (in mm) Spectral goniometric or directional reflectivity (implies knowledge of surface geometry & mineralogy) With this information could compute "emission spectrum" of areas of interest Attributes: Vertical & lateral distribution of major rock units, <u>in situ</u> temperature, monochromatic measurement of goniometric emittance in each petrologic and/or geometric rock unit	Approx. field of view: 4×10^{-4} steradians Area resolved on ground as a function of distancer from instrument: $A = 4 \times 10^{-4} r^2$ 1000' - 400 ft^2 5000' - 1×10^4 ft^2 10000' - 4×10^4 ft^2 20000' - $1.6 \times 10^5 ft^2$ 40000' - $6.4 \times 10^5 ft^2$ 10mi- 4×10^{-2} mi^2 50 mi- 1 mi^2 100 mi- 4 mi^2 200 mi- 16 mi^2 Recommended altitudes: 10' or less (ground surveys first.)	Record is smeared Integration time is uncertain, may be as long as 10 minutes (therefore high altitude flights are best to prevent ground smearing especially over fairly homogeneous terrain)	Agreeable

Contributor	Definition of ground truth & rock attributes to be studied	Resolution of sensors at various altitudes	Resolution & integration properties of sensor	Can sub-areas be selected to maximize ground truth?
William A. Fischer U.S.G.S.	(Infrared & ultraviolet studies) Ground truth - factors or elements that affect: the spectral, total or goniometric emission of IR energy the "UV reflectivity" of ground materials the emission of luminescent energy as a result of UV excitation Attributes: Temperature of surface; grain size, distribution and thickness of dust cover; configuration of surface; thermal conductivity, transmissivity & specific heat; chemical composition (wt. % of major oxides for IR; wt. % or ppm. of trace elements, particularly rare earths, for UV; may be modified pending study); mineralogy and petrographic description; Moisture; UV reflectivity; spectral distribution of UV stimulated luminescence, if any; total, spectral and goniometric emissivity.	1000' - 1 ft.^{2} 5000' - 25 ft.^{2} 10000' - 100 ft.^{2} 20000' - 400 ft.^{2} 40000' - 1600 ft.^{2} 10 mi - 2800 ft.^{2} 50 mi - 70,000 ft.^{2} 100 mi - 280,000 ft.^{2} 200 mi - 1,120,000 ft.^{2} Recommended altitudes: 1000' - 5000' higher later	Record is smeared for IR & passive UV, instantaneous for UV video. Scanning systems dwell time, 0.1 millisecond	Agreeable Would strongly recommend use of areas in which U.S.G.S. is establishing and marking ground control and will take low altitude photos with calibrated camera.
R.J.P. Lyon NASA	(Infrared) Ground truth - Bulk chemical composition & possibly SiO_2 & Fe-Mg ratios (Modal) Volume % of quartz, feldspar, pyroxenes & amphiboles (Major constituents) qualitatively & perhaps quantitatively Roughness & particle size of dust, sand or soil overlying the rock - if absent, then roughness & particle size of rock surface Attributes - Surface 1-2 cm is of maximum significance 1. Roughness, void %, particle size, depth of soil or dust 2. Bulk chemical composition, modal analysis (major) 3. Texture or fabric, on scales from 1 mm to 1m.	Resolution = instantaneous field of view + smear due to aircraft motion Instantaneous f.o.v. about .7 sq. degree 1000' - 7 x 30 5000' - 40 x 150 10000' - 75 x 300 20000' - 150 x 600 40000' - 300 x 1200 10 mi - 380 x 1540 50 mi - 3/8 x 1½ mi. 100 mi - 3/4 x 3 mi. 200 mi - 1½ x 6 mi. Recommended altitudes 1000, 5000, 10,000 feet	Integration time = about 1 sec. - The record is smeared Equipment uses a wavelength scanning grating $\therefore \lambda_1$ seen at point 1 and λ_2 seen at point 2 over the 1 second's time from 1→2. To a certain extent this will be correctable by the use of a <u>total radiometer</u>, sensing always over the band $\lambda_1 \rightarrow \lambda_2$ & with integration time of .01 sec. Cannot avoid problem in a moving vehicle with an experiment having a finite integration time.	Agreeable to 3 traverses. IR spectrometer, on tripod, can be focused on a source at 5 ft. F.O.V. is then 5×10^{-4} ft.^{2} (roughly .4 x 2.0 inches). Subareas could be 100 x100 ft. or 10 x 1000 ft. traverses. 3 recommended areas: 1. Crater rim, on a flat area perhaps SW side. 2. Portion of black, glassy-surfaced lava. 3. Portion of gray, rough-surfaced lava. (both 2 & 3 perhaps containing some overblown sand layers or "fingers" of lake

Contributor	Definition of ground truth & rock attributes to be studied	Resolution of sensors at various altitudes	Resolution & integration properties of sensor	Can sub-areas be selected to maximize ground truth?
Jack Green N. Amer. Avia.	(Microwave radiometry) Ground truth: Near surface temperature $\rho = \dfrac{2\pi c^2 h}{\lambda^5\left(e^{\frac{ch}{xT\lambda}} - 1\right)}$ in the λ range 8.5 mm to 10 cm Attributes: Many unknowns; must determine which are first, second or third order effects. 1. Moisture content as a function of depth of sensing (first order) 2. Gross lithology 3. Degree of alteration 4. Thermal conductivity 5. Emissivity 6. Degree of roughness in terms of λ 7. Grain size 8. Surface veneer (vegetation, etc.)	Resolution can be varied as a function of antenna diameter. For a dish 1 meter in diameter, vertical sensing will give the approx. resolutions: 5000' - few meters^2 100 mi- 2 km^2 Recommended altitudes: Any; can vary the dish diameter to give resolution required for the feature studied.	Record is smeared. Integration time is qualitatively very short. Not sure of exact figure. Same portion of spectrum is sensed over whole integration time.	Agreeable. Can provide Pisgah contour maps of 4 test squares 300 meters on a side with a contour interval of 25 cm. Also recommends: 1. Rift zone, Craters of the Moon, Idaho. 2. Cone alignment, Mono Craters, Calif. 3. Newberry caldera hot springs, lava tubes & associated features, Bend, Oregon. 4. Trident Volcano, Katmai, Alaska.

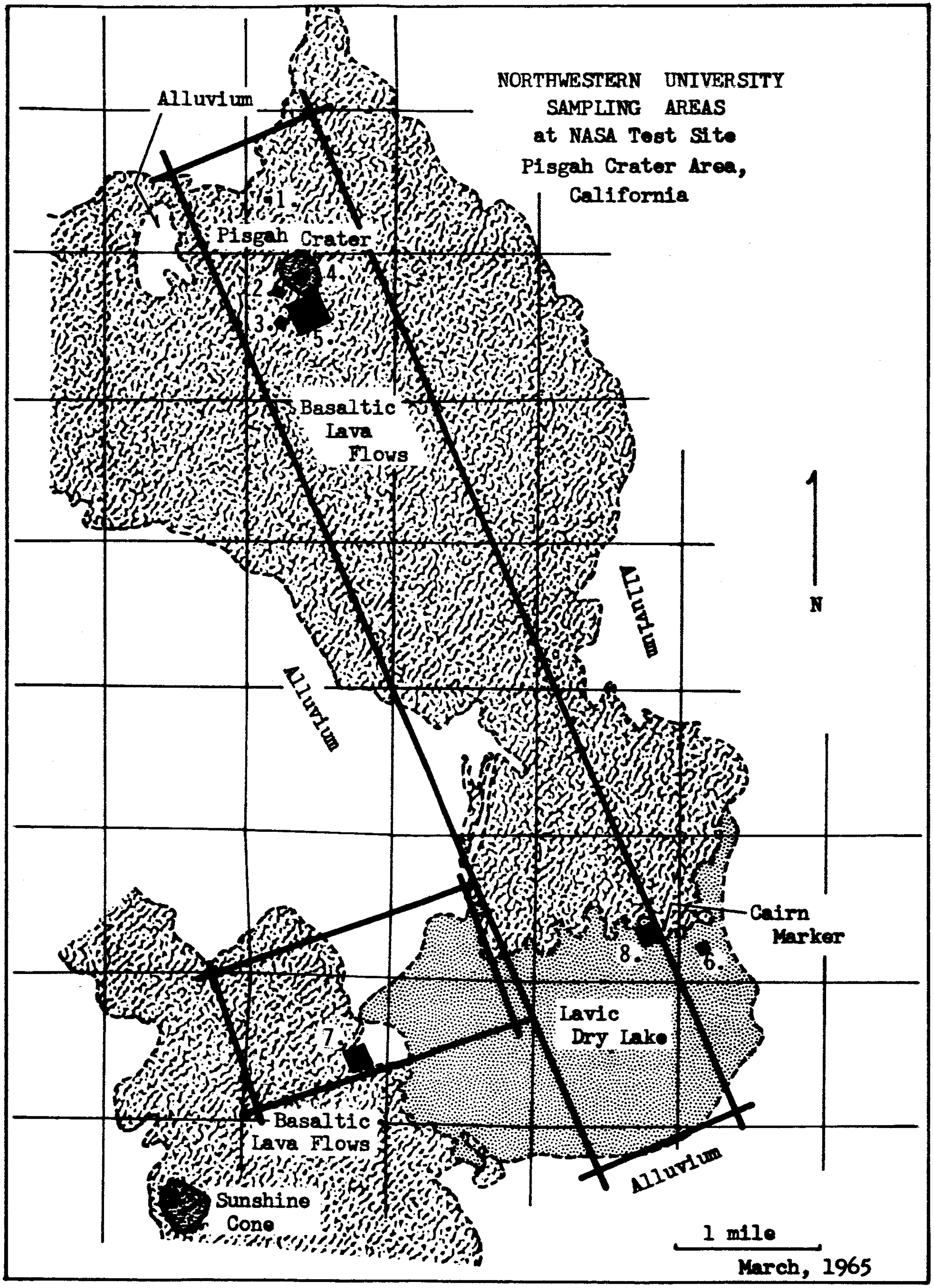
Contributor	Definition of ground truth & rock attributes to be studied	Resolution of sensors at various altitudes	Resolution & integration properties of sensor	Can sub-areas be selected to maximize ground truth?
D. S. Simonett U. of Kansas	(Radar) Ground truth has several components: A. Roughness 1. If greater than 2/10 scatters transmitted pulse and thus the magnitude of return signal (depending on degree of organization of roughness.) 2. Feasible to collect roughness data for longer wave-lengths (≥30 cm) since most surfaces are essentially rough for the shorter wave-length systems. B. Dielectric properties 1. Permittivity & conductivity related to contained water content of rocks and mineralogy. 2. Dielectric values for igneous, metamorphic and sedimentary rocks indicate some overlap. Generally, however, sedimentary rocks are more conductive than low-water igneous rocks. Variation in dielectric within single igneous rock type probably due to slight variations in contained water. 3. Thus, differences in dielectric properties probably not good basis for differentiating aa and pahoehoe; roughness may be significant at some wavelengths and some resolutions. 4. Recording of polarized and cross-polarized return signals may be sensitive to anisotrophic properties of the rocks and vegetation. Attributes: (Vegetation on lunar analogs can not be ignored; it will affect radar more so than other systems due to poorer resolution from aircraft altitudes.) A. Rocks 1. Textural features (grain size and shape). 2. Permittivity, conductivity 3. Superficial covering (saline clay, sterile quartz sand important) 4. Structural attributes (directional properties) 5. Surface features (roughness, slope angle and direction) 6. Moisture content, very important B. Other surface features (the properties of which affect return signal) 1. Vegetation 2. Snow (good penetration of dry snow) 3. Soils (for much of the earth can only sense soils derived from rocks) a. Temperature at 3" intervals to 3 feet b. Moisture content at surface and 3" intervals to 2 feet c. Other properties same as rocks 4. Cultural objects	Resolution: classified Recommended altitudes: 5000 to 40000 feet	Record is not smeared Integration time not relevant Senses same portion of spectrum	Agreeable 1. Aa free of sand cover 2. Pahoehoe free of sand cover

SPECIFIC SAMPLING AT PISGAH CRATER TEST SITE, CALIFORNIA:

Eight grids were laid out and sampled in February and March, 1965 (see Fig. 1). Several other sporadic locations were also sampled. A large variety of sampling methods (including photographic) was used in an attempt to test the variance and homogeneity of a wide variety of attributes in a representative selection of different lithologies. Widely dissimilar sample sizes were studied. Local magnetic disturbances and inadequate marking of the test site made it extremely difficult to locate accurate U,V-locations within the area.

The major areas sampled were:

I	NNW. of Pisgah Crater	- basalt flow overlapping outwash fan with blown sand
II	SW. of Crater	- small area of cinder-pavement and interspersed pahoehoe lava flow
III	SW. of Crater	- small area of aa basalt flow
IV	Inside Crater	- loose cinders in cone
V	S. of Crater	- large area of mixed pahoehoe and aa lavas
VI	Lavic Dry Lake (overlapping areas marked out by Lyon and Geol. Survey in Feb. 1965)	- playa with scattered basalt fragments
VII	On dog-leg site due south of Crater	- alluvial fan at mouth of stream: mixed basaltic and granitic debris
VIII	Immediately W. of red Survey cairn S. end of Pisgah flows	- mixture of interspersed lava flow and playa-like areas.


NORTHWESTERN UNIVERSITY
SAMPLING AREAS
at NASA Test Site
Pisgah Crater Area,
California
Alluvium
Pisgah Crater
1.
2.
3.
4.
5.
Basaltic
Lava
Flows
Alluvium
Alluvium
N
Cairn
Marker
8.
6.
7.
Lavic
Dry Lake
Basaltic
Lava Flows
Alluvium
Sunshine
Cone
1 mile
March, 1965

So far, preliminary numerical data have been prepared in the laboratory for Northwestern University Site I only. This site comprises a mixture of basalt, outwash gravel, and blown sand with spasmodic vegetation in a small area north of the crater (see Fig. 1). Dr. W. A. Fischer, in a personal communication in February 1965, said he anticipated viewing an area of 2 x 6 feet in the U. S. Geological Survey's initial airborne remote sensing experiments (this estimate allows for 'smear' effects due to aircraft speed during instrument integration time). On this basis a 24 x 24 feet grid was laid out and 49 surface samples were collected at 4 feet intervals. This grid size could be criticized on many counts, and in particular on the grounds that sensors will not have sufficient resolution to respond to such small closely-spaced samples. In order to get some direct information about the variables involved and to get an experiment initiated, a somewhat arbitrary sample grid seemed justified. Actually, it is difficult to know what resolution will be involved in initial remote sensing; Table IV shows that the following resolutions are expected:

TABLE V

<u>Experimenter</u>	<u>Sensor</u>		<u>Resolution</u>
Scheps	Radar	NRL aircraft at 2000'	200' x 160'
		WADC aircraft (photo record)	50' x 50'
		<u>Classified</u> aircraft	high resolution*
Conel	Infrared spectrophotometry	at 1000'	400' x 400'
Fischer	Infrared and Ultrviolet	at 1000'	1' x 1'
Lyon	Infrared	at 1000'	7' x 30'
Green	Microwave radiometry	at 5000'	few square meters
Simonett	Radar	-	<u>classified</u>*

* <u>N.B.</u> TIME for March 26, 1965 (Vol. 85, No. 13, pp. 85-6) noted

that the "sharp-eyed, long-range radars of the North American Air Defense Command watched the launch of the Voskhod II and followed it in orbit ... they saw an irregularity develop in the spaceship's electronic "signature"" when Leonov opened the hatch to emerge from the capsule. TIME also reported that the apogee of Voskhod II's elliptical orbit was 307.5 miles above earth. This unclassified information gives some idea of the high resolution possible with some radar.

Each station at Site I was photographed, and numerous attributes are being measured on the photos. Since grain size appears to affect some sensors, mechanical analyses have been run on the collected samples and the composition of the several fractions is being analysed. With the aid of these measurements the areal variability of a variety of attributes is being assayed with the aid of several computer programs. A large volume of results has come to hand within the past two or three weeks, and these will be made available in the near future.

Other experiments that have produced useful results include:

(i) Statistical analyses of the size and distribution of different lithologies recognizable on Dr. Colwell's large-scale air photographs.

(ii) Optical Fourier transform analyses have been attempted on a few representative air photographs in the hope of developing a technique for assessing the homogeneity of lithologies.

(iii) Three areas in the Pisgah region have been subjected to elementary topographic analysis; data derived from contour maps of the Pisgah cone, Sunshine Peak, and from a neighboring alluvial fan have been subjected to discriminant analysis with useful results.

The full results of all these analyses will require considerable explanatory text, so it is appropriate to reserve them for inclusion in a more formal paper in the near future.

FIELD WORK, MEETINGS, AND CONSULTATIONS:

Meetings attended:

1. Geoscience Test Site Committee Meeting, Ann Arbor, Michigan, October 12-13, 1964, attended by Whitten, Howland, Beckman. On October 13 a special evening session was sponsored by the Northwestern team to consider the statistical problems of ground truth.

2. Radar Team Coordination Meeting, Lawrence, Kansas, December 15-16, 1964, attended by Beckman.

3. Geoscience Test Site Committee, Washington, D. C., March 17, 1965, attended by Whitten.

Field work:

1. February 8-12, 1965, Pisgah Crater Test Site: Whitten and Beckman.

2. March 22-28, 1965, Pisgah Crater Test Site: Whitten, Beckman, and Thomas.

Consultations:

1. Dr. Jules Freedman, U. S. Geological Survey, visited Northwestern University on January 25, 1965.

2. Sampling methodology was discussed with several team representatives (particularly the U. S. Geological Survey team) in the field at Pisgah Crater Test Site in February, 1965.

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Vistelius, A. B., 1962, Phosphorus in granitic rocks of central Tien Shan: Geochemistry, v. 1962, pp. 131-51.

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